

Implementation of Web-Based Virtual Laboratory Media in Learning

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Abstracts. The integration of information and communication technology in learning through the application of virtual laboratory media can be an alternative solution to overcome the constraints of time, cost, and laboratory safety in biology labs. Virtual laboratories are very suitable to be applied to the mechanism of evolution because they involve the context of space and time, and can provide opportunities for students to learn independently and increase active student involvement in learning. These study aims are to determine the effect of the application of virtual laboratory media on the understanding of student concepts; knowing increasing students' understanding of the concept of evolutionary mechanisms, and knowing students' responses after learning with virtual laboratories. This type of research is a pre-experimental design (nondesign) with one group pretest-posttest design. The research subjects were 37 students. The media used as many as 8 web-based virtual laboratory programs (online) that can be freely accessed. Data collection techniques include tests (pretest and posttest) and questionnaires. The pretest and posttest values were analyzed by the T-test while the questionnaire data were analyzed descriptively. The application of web-based virtual laboratory media on the evolution mechanism material influences the understanding of student concepts ($t_{\text{arithmic}} > t_{\text{table}}$ then H_0 is rejected and H_1 is accepted) The application of these media increases students' understanding of the concept of evolutionary mechanisms. The mean value increased from pretest 23.65 to 56.08 at the posttest with an increase of 32.43. Student responses to the application of media in learning showed 91.89% of students felt helped in understanding the process of evolution while 100% of students felt helped in understanding the role of evolution in causing evolution.

Keywords: media, virtual laboratory, evolution mechanism, evolution

INTRODUCTION

Constructivism in learning means that knowledge is the result of the formation of someone who knows something. Someone who studies will form understanding. This understanding is formed actively, not only passively accepted by the student [1]. Knowledge is not only transferred from the teacher to students but is interpreted by students themselves according to student experiences. Various types of experience are provided by the teacher so that students can construct their knowledge, one of these experiences is practicum. Practicum provides a deeper learning experience because students can directly practice the experiments related to the learning material.

Exercises in learning biology are faced with time problem [2]; safety for using the tools, chemicals, and biological agents; high laboratory operational costs and limited laboratory equipment facilities [3]. Biology exercise can not be separated from the threat of laboratory

accidents that might occur such as adverse chemical reactions, burns, and infections by biological agents [4]. To overcome this, the integration of information and communication technology (ICT) in learning through the use of computer-based learning tools such as virtual field trips, computer simulation, and virtual laboratory can be an alternative solution [3]. ICT integration appears in the use of instructional media in the form of virtual technology and simulations. Virtual and simulation technology can construct phenomena that occur in nature through visual representations and simulations that are evident based on real phenomena that occur in nature [4] [5]. The simulation that shows the experiments according to the description of the real environment (virtual experiment) is a virtual laboratory [6].

The virtual laboratory can facilitate students in gaining interactive experiences and manipulating objects to get data so the virtual laboratory can accommodate the discovery

learning and inquiry models. The virtual laboratory has advantages such as giving the evaluations of experiments that have a problem in time, cost, and laboratory safety constraints if compared in real conditions [6]. Virtual laboratory simulations can provide opportunities for students to learn independently, increase active student involvement in learning activities and improve the quality of learning [2] [5]. Learning organized using technology-based learning media can create a more creative, innovative and interesting learning atmosphere so that it can increase student interest in learning [5].

The superiority of virtual laboratory in overcoming the limited time of conducting experiments and its ability to represent real phenomena visually becomes a consideration for applying virtual laboratory-based learning in evolution courses. In the evolution course, some materials are considered abstract, for example, the mechanism concept of evolution, and if it will be practiced, it requires a very long time because it involves several generations of offspring. According to [2], evolution is very appropriate to be conveyed by computer media because it involves the context of space and time. One of the web-based virtual evolution laboratory that is operated online (<http://biologylab.awlonline.com/>) allows students to observe 300 years of finch evolution on 2 islands.

The mechanism of evolution is more commonly known at the level of visually visible macroscopic representation of changes slowly in traits passed down from one generation to the next. However, at the level of sub-microscopic representation, the mechanism of evolution is the change in allele frequencies in one generation to the next [7]. Understanding at the level of sub-microscopic representation is often poorly understood by students because it seems abstract. This has an impact on understanding the concept to be incomplete. The application of virtual laboratory in this study is considered very appropriate because it can describe changes in allele frequencies in several generations of offspring to increase understanding at the level of sub-microscopic representation [8].

Virtual laboratory has been developed and have been widely applied in science learning in high school and vocational schools, especially physics and chemistry including core physics material [9]; dynamic electricity [10]; vibrations and waves [11]; oscillations [12] and reaction rates [8]; while in colleges includes robotics laboratories [13]; architecture [6]; bioinformatics [14]. The implementation of a virtual laboratory in biology learning in colleges for biology education

program students needs to be further enhanced given the advantages of the media. The aims of the study are to determine the effect of the implementation of virtual laboratory media on the understanding of student concepts; know increasing for an understanding of the concept of evolutionary mechanisms, and know the responses after the students learn the concepts with virtual laboratory. Information about students' responses to the virtual laboratory used, about the ease of use of the media and its potential to provide material information, is very important as a basis for supporting the use of the media in further learning.

METHOD

This type of research is a pre-experimental design (non-design). The design uses a one-group pretest-posttest. This design compares the situation before and after being given treatment through the pretest and posttest [15]. The subject of the study is a class of students who participate in the evolution course (anthropology) in the 2nd semester of 2016/2017 in the Biology Education Study Program as many as 37 students. The class is given a pretest to find out the student's initial understanding of the evolution mechanism and the posttest is given after the student gets learning experience using virtual laboratories media to find out the student's understanding after being given treatment.

Data collection techniques are tests and questionnaires. The data collection instruments are a test sheet to measure the understanding of the concept of evolutionary mechanisms and a questionnaire to determine student responses after experiencing learning with virtual laboratory media. The question in the test sheet is 5 essay questions covering the process of evolution (the mechanism of evolution) which involves the role of 5 factors causing the evolution of organisms. Indicators for increasing understanding of the concept of evolutionary mechanisms are seen from the results of the pretest and posttest. The pretest and posttest scores were analyzed by the T-test to find out the differences between pretest and posttest.

The questionnaire consists of 4 questions related to the use of virtual laboratory media in learning which included difficulties in understanding the virtual laboratory and the benefits of the program. The questionnaire data are analyzed descriptively.

There are 8 programs of virtual laboratory media in this study (Table 1.), all web-based (operated online) and can be accessed without paying. The program displays a simulation of the

evolutionary process that is affected by each of the 5 evolutionary factors (selection, migration, mutation, gene drift, and non-random marriage) as well as a combination of 2 or more factors. In each program, there is information on the

evolutionary mechanism that is modeled (summary theory), simulation procedures, experimental simulations, and experimental results data.

Table 1. URL of Virtual Laboratory Program

No.	Virtual Laboratory Program	URL
1.	<i>How can natural selection be modeled?</i>	http://www.glencoe.com/sites/common_assets/science/virtual_labs/LS06/LS06.html
2.	<i>Evolution lab</i>	http://www.biologyinmotion.com/evol/index.html
3.	<i>Random Genetic Effects</i>	http://virtualbiologylab.org/NetWebHTML_FilesJan2016/RandomEffectsModel.html
4.	<i>Natural selection</i>	http://glencoe.mheducation.com/sites/dl/free/0078802849/383939/BL_12.html
5.	<i>PopGen Fishpond</i>	http://virtualbiologylab.org/ModelsHTML5/PopGenFishbowl/PopGenFishbowl.html
6.	<i>PopGen Fishbowl</i>	http://virtualbiologylab.org/NetWebHTML_FilesJan2016/PopGenFishbowlModel.html
7.	<i>Industrial Melanism</i>	http://virtualbiologylab.org/NetWebHTML_FilesJan2016/IndustrialMelanismModel.html
8.	<i>Endler's Guppies</i>	http://virtualbiologylab.org/NetWebHTML_FilesJan2016/EndlersGuppiesModel.html

RESULT AND DISCUSSION

- Understanding the concept of the mechanism of evolution

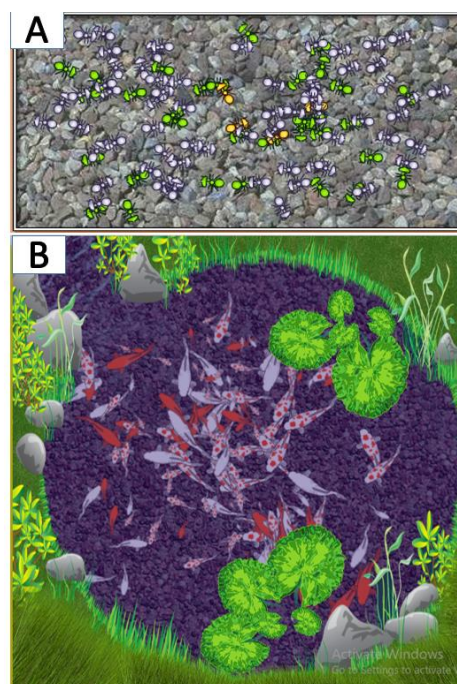
Based on Table 2. virtual laboratory media can improve students' understanding of the concept of the evolutionary mechanism. The average score of the posttest (56.08) after being given a learning treatment with virtual laboratory media is higher than the average score of pretest (23.65). The average pretest-posttest score increases to 32.43.

T-test of the pretest and posttest scores show that the t arithmetic $>$ t table ($11.82 > 2.02$) at $\alpha = 0.05$. Based on this analysis, H_0 is rejected and H_1 is accepted which means that there is a significant difference between the pretest and posttest scores. Thus it can be concluded that the implementation of web-based virtual laboratory media on the evolution mechanism material influences the understanding of student concepts.

Table 2. Pretest and Posttest Score

Component	Pretest	Posttest
Number of Student	37 students	37 students
Highest Score	60	85
Lowest Score	0	20
Average	23.65	56.08
Standard Deviation	13.72	19.08
Variance	188.40	364.08

The application of virtual laboratory media in learning can improve students' understanding of the concept of evolutionary mechanisms. This is because the application of a virtual laboratory makes learning more interesting so students become more enthusiastic and motivated to learn. With a virtual laboratory, the students learn like playing computer games.



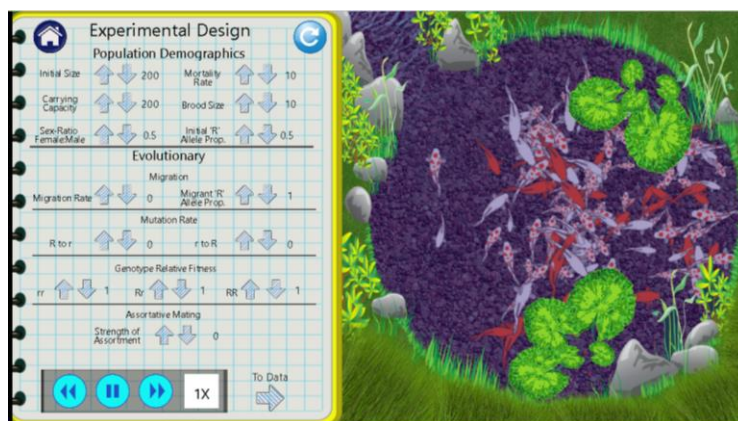
Picture 1. Ants (A) and Koi Fishes (B) in the Virtual Laboratory Program

The virtual laboratory used shows examples of organisms that have a process of evolution visually through moving animated images (eg. rabbits, ants, butterflies, guppies and koi fish) so that they appear more attractive (Figure 1.). In research [9], students strongly agree with the implementation of the virtual laboratory in learning because they are interested in the display of simulations and easier to do so they enjoy to study. According to [11], students show an interest in virtual laboratory media. By using virtual laboratory media, the learning atmosphere becomes more lively, excited and increased learning students' motivation.

The virtual laboratory provides opportunities for students to conduct experiments and construct their knowledge based on virtual experiment experience. The use of virtual laboratory also provides students the opportunity to be actively involved in learning not only to take notes and listen and provide opportunities for exploration [9]. The active involvement of students appears from experiments conducted with scenarios that are determined by the students themselves. Figure 2. shows that to be able to conduct experiments, students must first determine including initial population size

(carrying size), carrying capacity (carrying capacity), female and male sex ratio (sex-ratio female-male) and the speed of death (mortality rate). Because the virtual laboratory is implemented on a web-based basis, the experimental results have the advantage of being able to show different data based on manipulations performed [2]. In addition to active involvement in learning, the virtual laboratory can also improve the ability to think creatively through the evolutionary process of imagination as desired by students [11].

The virtual laboratory provides independent learning opportunities. In this study, students are assigned to do experiments using virtual laboratory in groups but the experiments could also be done individually outside the classroom. Students have the freedom to determine when and where to study [11]. Students are responsible for the planning and implementation of learning. If they do not understand the material being studied, students have the opportunity to carry out repeated experiments as needed [2]. Thus, the virtual laboratory can assist individual, group and mass learning processes.



Picture 2. The Display of Virtual Laboratory Program of *PopGen Fishpond*

- *Pretest and Posttest*

Improved student understanding is measured through pretest and posttest. Table 3. shows that mutation as an evolutionary factor can be explained by 50% with students and selection can be explained by 47.62% of students by a score of 1. Based on the results of the pretest, the evolutionary factors that cannot be explained by most students are migration (90, 48%), non-random mating (85.71%) and genetic drift (85.71%).

Table 3. Pretest score of evolution factors (evolution mechanism)

Point of Answer	Student Percentage (%)				
	Mutation	Selection	Migration	Non-Random Mating	Genetic Drift
0	9,52	9,52	90,48	85,71	85,71
1	23,81	47,62	2,38	4,76	9,52
2	7,14	33,33	7,14	7,14	4,76
3	9,52	2,38	0,00	0,00	0,00
4	50,00	7,14	0,00	2,38	0,00
Total	100	100	100	100	100

Mutations can be explained precisely by 50% of students (score 4) because students have gotten that material in the Genetics and Adaptation course which is a prerequisite course of the Evolution course. Meanwhile, selection can be explained by 47.62% of students with a score of 1 because this factor is explained in Darwin's Theory that is quite popular with students. The aspect that is not yet explained by students in the selection role in evolution is only individuals who have beneficial traits will survive, while individuals who have less favorable characteristics will die and will not be seen again in subsequent generations. Based on students' answers there is a misunderstanding of adaptation in evolution. Students recognize adaptation as an adaptation to their environment so that what is active is their organism while the meaning that is appropriate for adaptation in evolution is to refer to adaptive traits. So in the process of adaptation, variants of organisms will be selected (natural selection) so that in this case the more active is the selector, not the organism.

Students are almost entirely unable to explain migration, non-random marriages and genetic drift in evolution. A misunderstanding that often arises in explaining migration as a factor in evolution is that students cannot separate migration from the selection. Most students explain that if some individuals in a population move to another location (migration) then these individuals will adapt to the population in the new location and environmental conditions. The students' understanding is still classified in selection (natural selection). The right understanding of the role of migration in evolution is that migration will decrease the frequency of the alleles at the abandoned location and the increase of the alleles at the intended location. Misunderstanding for the role of migration can be overcome by the PopGen Fishpond and PopGen Fishbowl virtual laboratory programs.

In the PopGen Fishpond virtual laboratory program, it is illustrated that the body color of a fish is determined by the allele R and r. The simulation involves fish with 3 types of colors namely orange (RR), orange patches (Rr) and white (rr). If the moving fish are orange, it will reduce the R allele in the population in the abandoned pond, as a result in subsequent generations there will be a decrease in the number of orange and orange patches in the population. Conversely, in the intended pond, there will be an increase in allele R so that in later generations

there will be an increase in the number of orange-colored fish and orange spots.

Posttest assessment shows an increase in student understanding, especially on factors of migration, non-random marriage and gene drift (Table 4.). All three are factors that most students cannot explain and score 0 (zero) in the pretest (Table 3.). Among the three factors, migration is the factor that experienced the highest increase because students who could not explain at all (score 0) were only 2.56%.

The use of the PopGen Fishpond and PopGen Fishbowl virtual laboratory programs helps students understand migration factors as the cause of evolution. This is shown from the selection of examples of migration events written by students on the posttest answer sheet, namely fish migration. Of the 10 students who gave examples of migration events, 4 of them used fish samples while lizards of 2 students, birds of 2 students, dragonflies of 1 student and humans of 1 student.

Table 4. Posttest score of evolution factors (evolution mechanism)

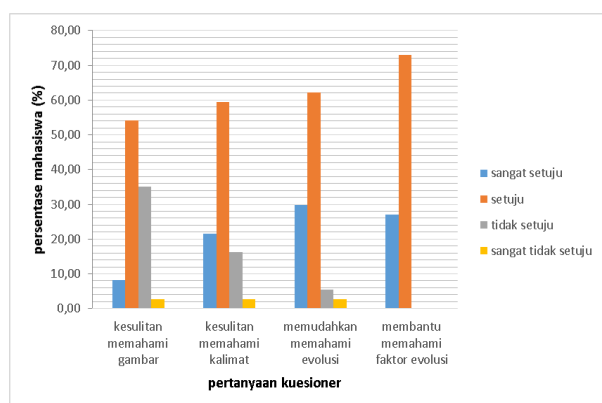
Point of Answer	Student Percentage (%)				
	Mutation	Selection	Migration	Non-Random Mating	Genetic Drift
0	7,69	0,00	2,56	20,51	41,03
1	17,95	2,56	43,59	10,26	23,08
2	12,82	51,28	15,38	7,69	23,08
3	12,82	25,64	10,26	30,77	2,56
4	48,72	20,51	28,21	30,77	10,26
Total	100	100	100	100	100

The gene drift factor in evolution is usually exemplified through two events, the founder effect and the bottleneck effect, but in the virtual laboratory program that is used only represents the founder effect. These limitations cause the results of an increased understanding of students less than the maximum. Only 10.26% of students were able to explain correctly (score 4) while 23.08% of students got a score of 1; 23.08% of students got a score of 2; 2.56% of students got a score of 3. Some students were less able to distinguish the founder effect from migration. Founder effect and migration have similarities in the stages of the movement of individuals to other locations but at the founder effect, the intended location is new and has never been inhabited by a population of these species while in migration, the

intended location is a location that is also a habitat for the type of organism.

The choice of learning media should adjust to the learning objectives, objectives, media characteristics, time, cost and availability of the media [16]. The virtual laboratory program that was chosen in this study also considers the quality of the media including the ease of use of the media and its potential in delivering the material.

Based on Figure 3, as many as 8.11% (strongly agree) and 54.05% (agree) students have difficulty understanding the images in a virtual laboratory while 21.62% (strongly agree) and 59.46% (agree) students have difficulty understand the sentences in the media. Most students have difficulty in understanding sentences in the laboratory virtual media used because the media uses the English language. That problem causes students to have difficulty understanding simulation information (summary theory) and the subsequent simulation procedure results in difficulties in understanding the pictures in the program.



Picture 3. Student Responses to Virtual Laboratory

The virtual laboratory media selected in this study is the media that have good quality. *Natural Selection and How can natural selection be modeled?* is one of the web-based virtual laboratory programs (online) from McGraw-Hill Education. This media was chosen because of the limited virtual laboratory related to evolution material. There is no virtual laboratory media about the evolution mechanism in Indonesian that can be accessed without pay. The virtual laboratory is considered to be very suitable to be applied in learning the mechanism of evolution but the limitations of the media become an obstacle so that for further research more virtual laboratory media must be developed to support evolutionary learning.

Although students have difficulty understanding images and sentences in the virtual

laboratory program used, the application of the media in learning is assessed by students to help understand the material. As many as 29.73% (strongly agree) and 62.16% (agree) students felt helped in understanding the process of evolution while 27.03% (strongly agreed) and 72.97% (agreed) students felt helped in understanding the role of the evolution factor in causing evolution to occur.

CONCLUSION

Implementation of web-based virtual laboratory media in learning of the evolution mechanism material influences the understanding of student concepts (t arithmetic > t table then H0 is rejected and H1 is accepted). The implementation of these media can improve students' understanding of the concept of evolutionary mechanisms. The average score increased from pretest 23.65 to 56.08 at the posttest with an increase of 32.43. Student responses to the implementation of media in learning showed 91.89% of students felt helped in understanding the process of evolution while 100% of students felt helped in understanding the role of evolution in causing evolution.

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